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Expanding the realm of 'classical' electrodynamics

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Abstract : This paper argues that a fairly straightforward revision of the current 'relativistic' theory of electrodynamics turns it into an essentially 'classical' theory that is capable of addressing both relativistic and 'quantum' phenomena. This kind of unification removes the many paradoxes of special relativity theory and the many mysteries of quantum mechanics, and restores electrodynamics to its deservedly fundamental place in the development of physical theory.

Keywords : Electrodynamics, classical charged particles, special relativity, quantum mechanics.

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1. Introduction

The term 'classical' as applied to electrodynamics refers first of all to its early developers, who sought to describe electromagnetic interactions in a Newtonian way, with instantaneous and balanced interactions between charges, and between current elements. These early developers include Weber, Gauss, Neumann, Ampère, and others. The efforts undertaken often had the objective of more and more correctly calculating effects on particles or current elements due to other particles or current elements, taking account of not only of the positions of all the particles and current elements (the Newtonian paradigm), but also the velocities of those particles and current elements, and even their accelerations.

Maxwell took a quite different approach. He emphasized, not the particles or the current elements themselves, but rather the fields that they were presumed to create. The difference between Maxwell and the others is like the difference between 'democratic' and 'autocratic'. In the early developer's theories, the Newtonian approach lends itself naturally to a 'two-body' problem, where two charges or two current elements affect each other reciprocally, with equal and opposite force. In Maxwell's theory, one set of 'source' charges or currents creates the fields, while another 'test' charge or current elements, having insignificant magnitude, responds to the fields but does not react upon their source particles and current elements The scenario is basically a 'one-body' problem

It is unclear whether the term 'classical' should apply to Maxwell's electromagnetic theory (EMT) On the one hand, Maxwell's work was the foundation upon which Einstein built his Special Relativity Theory (SRT), and SRT is generally considered totally distinct from 'classical' mechanics because it has 'variable mass' and other such oddities But on the other hand, Maxwell's work definitely was too 'classical' to describe the many strange phenomena that later led to the development of modern Quantum Mechanics (QM), which is the ultimate in 'non-classical' because if features 'uncertainty' and 'probability' which Newtonian dynamics did not use

The present paper attempts to resolve this conundrum It revisits Maxwell, and Einstein and QM It argues that a relatively simple revision of the current 'relativistic' theory of electrodynamics turns it into a 'classical' theory, and this 'classical' approach is capable of addressing both 'relativistic' and 'quantum' phenomena This development represents a kind of 'unification' in physics Such unifications used to be much desired in physics Just recall Newton's unification of earthly and celestial dynamics, or Maxwell's unification of electrical and magnetic phenomena But in the twentieth century, we really saw more fragmentation than unification And the one kind of unification that was sought most fervently namely that between General Relativity Theory (GRT) and QM, has remained totally elusive

The present program of research has a more modest scope unification of classical electrodynamics, relativistic physics, and atomic physics But within that scope, it removes the many paradoxes of special relativity theory and resolves the many mysteries of quantum mechanics, and it restores electrodynamics to its deservedly fundamental place in the development of physics theory

2. A puzzling problem in EMT

What the world today accepts concerning the potentials and fields created by rapidly moving source charges is expressed by formulae derived by Liènard and Wiechert [1,2] In Gaussian units [3], the Liènard-Wiechert scalar and vector potentials are

$$\Phi(\boldsymbol{x},t)=e\left[1/\kappa R\right]_{\text{retarded}} \quad \text{and} \quad \boldsymbol{A}(\boldsymbol{x},t)=e\left[\boldsymbol{\beta}/\kappa R\right]_{\text{retarded}} \tag{1a}$$

where $\kappa=1-\boldsymbol{n}\bullet\boldsymbol{\beta}$, with $\boldsymbol{\beta}$ being source velocity normalized by c, and $\boldsymbol{n}=\boldsymbol{R}/R$ (a unit vector), and $\boldsymbol{R}=\boldsymbol{r}_{\text{observer}}(t)-\boldsymbol{r}_{\text{source}}(t-R/c)$ (an implicit definition for the terminology 'retarded') The Liènard-Wiechert fields expressed in Gaussian units are then

$$\boldsymbol{E}(\boldsymbol{x},t)=e\left[\frac{(\boldsymbol{n}-\boldsymbol{\beta})\left(1-\beta^2\right)}{\kappa^3R^2} \quad \frac{\boldsymbol{n}}{c\kappa^3R}\times\left((\boldsymbol{n}-\boldsymbol{\beta})\times\frac{d\boldsymbol{\beta}}{dt}\right)\right]_{\text{retarded}}$$

and $$\boldsymbol{B}(\boldsymbol{x},t)=\boldsymbol{n}_{\text{retarded}}\times\boldsymbol{E}(\boldsymbol{x},t)$$

The $1/R$ fields are radiation fields, and they make a Poynting vector that lies along $\boldsymbol{n}_{\text{retarded}}$

$$\boldsymbol{P} = \boldsymbol{E}_{\text{radiative}} \times \boldsymbol{B}_{\text{radiative}} = \boldsymbol{E}_{\text{radiative}} \times (\boldsymbol{n}_{\text{retarded}} \times \boldsymbol{E}_{\text{radiative}}) = E^2_{\text{radiative}}\boldsymbol{n}_{\text{retarded}} \tag{1c}$$

But the $1/R^2$ fields are Coulomb-Ampère fields, and the Coulomb field does not lie along $\boldsymbol{n}_{\text{retarded}}$ as one might naively expect, instead, it lies along $(\boldsymbol{n}-\boldsymbol{\beta})_{\text{retarded}}$

Consider the following scenario, designed specifically for an instructive exercise in *reductio ad absurdum* A source executes a motion comprising two components . (1) inertial motion at constant $\boldsymbol{\beta}$, plus (2) oscillatory motion at small amplitude and high frequency, so that there exists a small velocity $\Delta\boldsymbol{\beta}_{\text{retarded}}$ and a not-so-small acceleration $d\Delta\boldsymbol{\beta}/dt|_{\text{retarded}}$ Observe that the radiation and the Coulomb attraction/repulsion come from different directions The radiation comes along $\boldsymbol{n}_{\text{retarded}}$ from the retarded source position, but the Coulomb attraction/repulsion lies along $(\boldsymbol{n}-\boldsymbol{\beta})_{\text{retarded}}$, which is basically $(\boldsymbol{n}_{\text{retarded}})_{\text{projected}}$, and lies nearly along $\boldsymbol{n}_{\text{present}}$. This behavior seems peculiar Particularly from the perspective of modern Quantum Electrodynamics (QED), all electromagnetic effects are mediated by photons – real ones for radiation an virtual ones for Coulomb-Ampère forces How can these so-similar photons come from different directions ?

The following Section sets out to remove this paradox

3. Expanded SRT

Einstein [4,5] elevated an idea that had emerged from study of Maxwell to the status of a founding Postulate for Special Relativity Theory (SRT) Maxwell had the free-space electric permittivity ε_0 and and magnetic permeability μ_0, which together imply a light speed c Einstein's famous 'Second Postulate', asserted this light speed to be the same constant for all inertial observers, independent of any particular circumstance, such as source motion

Inasmuch as SRT is founded on Maxwell's theory, and Maxwell's theory cannot handle the Hydrogen atom, SRT is unlikely ever to be fully compatible with QM Einstein was involved in the development of QM, through his Nobel-Prize winning work on the photoelectric effect, but he was not fond of QM, and in later years did not work so much on it Instead, he mainly went back to SRT, embraced the Minkowski tensor formulation for it, and exploited the metric tensor therein the develop GRT

GRT has the same fundamental character as Maxwell's theory . it is a field theory, and as such, it is not designed for something so complicated as a two-body problem. It is the extreme opposite to Newton's point-particle theory, which excels on the two-body problem. Late in life, Einstein wrote to his friend M A Besso about his misgivings concerning field theories :

> I consider it quite possible that physics cannot be based on the field concept, *i e* on continuous structures In that case *nothing* remains of my entire castle in the air, gravitation theory included, [and the] rest of physics

Acknowledging such doubts is I believe, the mark of a truly great scientist Einstein s present-day followers usually do not harbor such doubts

But SRT has produced an extensive literature about 'paradoxes', especially featuring twins, clocks, trains, meter sticks, or barns, or spinning disks, *etc* So there have always been researchers questioning Einstein's Second Postulate, and evaluating alternatives to it Ritz [6] was an early, but unsuccessful, example Later, in the 1950's, began the work of P Moon, D Spencer, E Moon, and many of Spencer's students [see [7–9] and additional references cited therein] Their work has been successful in producing a lot of very interesting results, if not in garnering all the recognition it really deserves

The key Moon-Spencer-Moon *et al* idea was a propagation process with continuing control by the source, even after the initiating 'emission' event, so that the light moves away from the source at speed c relative to that source, however arbitrarily the source itself may be moving (This is *not* the Ritz postualte, which had the light moving at velocity $\mathbf{c} + \mathbf{V}$, where $\mathbf{V}$ was the velocity vector of the source at the moment of emission and $\mathbf{c}$ is the velocity vector of the light if it had come from a stationary source at that moment)

In any event, continuing control by the source implies that 'light', whatever it is, has a longitudinal extent (Of course ! Light possesses wavelength, does it not ?) and the longitudinal extent is expanding in time That expansion naturally raises the question exactly what *feature* of the expanding light packet is it that moves at speed c relative to the source ? The tacit hypothesis of Moon-Spencer-Moon *et al* is that the c-speed part is the leading tip of the light packet It then follows that when a receiver is encountered, the entire longitudinal extent of the light packet must collapse instantly to the receiver That means the trailing tail of the light packet must snap into the receiver at infinite speed The infinite speed might be unacceptable for Einstein true believers, but may be not for QM true believers

My own work [10,11] follows the Moon-Spencer-Moon *et al* lead, with one conceptual addition, namely, that the speed c relative to the source characterizes, not the leading tip of the light packet, but rather the mid point of the light packet That means the leading tip must move relative to the source, not at c, but rather at $2c$ [A $2c$ anywhere is probably shocking to Einstein true believers, but maybe not so shocking as an infinite speed would be]

This variation on the Moon-Spencer-Moon *et al* theme allows symmetry between light emission and absorption The leading tip of the light packet reaches the receiver in half the time for propagation at c, so there is time left for a completely symmetric absorption process, wherein the mid point of the light packet travels at speed c relative to the receiver, however arbitrarily that may move That idea then means the tail end reels in at speed $2c$ relative to the receiver

The revised light postulate is what I have called 'Two-Step Light'. It is illustrated in Figure 1. The T's are Universal Times: T_0 at the beginning of the scenario, T_1 at the mid point, and T_2 at the end. Particle A is the source, and particle B is the receiver (one of possibly many candidate receivers, selected by the accidental collision with the expanding light arrow at T_1).

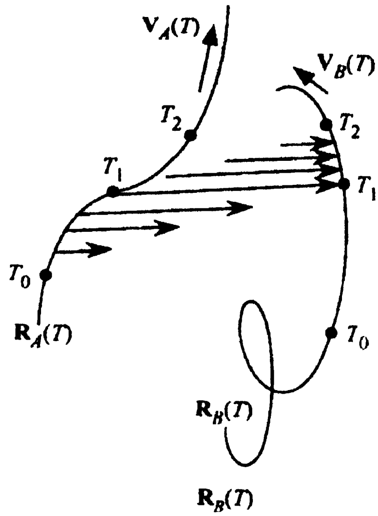

Figure 1. Illustration of Two-Step Light propagation.

The mid points of the light arrows may be said to resemble the Moon-Spencer-Moon *et al* favored postulate in the expansion phase of the scenario, and then with the Einstein postulate in the collapse phase of the scenario. How can light do all that ? Stay in contact with a moving source ? Switch control to a moving receiver ? Stay in contact with a moving receiver ? At this point, I must follow Newton, who answered all such 'how' questions with the phrase *hypothesis non fingo*. My first job is just to work out the implications of the Two-Step Light Postulate. It is a straightforward task, involving just algebra. It has been detailed in [10,11]; here I shall just summarize results.

Consider the problem of processing data consisting of successive light signals from a moving source in order to estimate the speed V of that source. If the light propagates according to the Two-Step process, but the data gets processed under the assumption of the one-step Einstein postulate, then there will be a systematic error to the estimate. In fact, the estimate turns out to be

$$v = V\Big/\left(1 + V^2\big/4c^2\right) \tag{2}$$

The estimate v is always less than V, and in fact is limited to c, which value occurs at $V = 2c$. Thus v has the property that is characteristic of any observable speed in Einstein's SRT. The obvious implication is that v is an Einsteinian speed, whereas V is a Galilean speed.

One is obviously invited to look also at a related construct

$$V^{\uparrow} = V/\left(1 - V^2/4c^2\right) \tag{3}$$

The superscript $\uparrow$ is used to call attention to the fact that $V^{\uparrow}$ has a singularity, which is located at $V = 2c$, or $v = c$ That is, $V^{\uparrow}$ has the property of the so-called 'proper' or covariant' speed Interestingly, past the singularity, $V^{\uparrow}$ changes sign This behavior mimics the behavior that SRT practitioners attribute to 'tachyons', or 'super-luminal particles they are said to 'travel backwards in time' The sign change is a mathematical description while the 'travel backwards in time' is a mystical description

The relationships expressed by (2) and (3) can be inverted, to express V in terms of v or $V^{\uparrow}$ The definition $v = V/\left(1 + V^2/4c^2\right)$ rearranges to a quadratic equation $\left(v/4c^2\right)V^2 - V + v = 0$, which has solutions

$$V = \frac{1}{v/2c^2}\left(+1 \pm \sqrt{1 - v^2/c^2}\right) \tag{4a}$$

Multiplying numerator and denominator by $\left(+1 \mp \sqrt{1 - v^2/c^2}\right)$ converts these to the form

$$V = v\Big/\frac{1}{2}\left(+1 \mp \sqrt{1 - v^2/c^2}\right), \tag{4b}$$

which makes clear that for small v, V has one value much, much larger than v and another value essentially equal to v

Similarly, the definition $V^{\uparrow} = V/\left(1 - V^2/4c^2\right)$ rearranges to a quadratic equation $\left(-V^{\uparrow}/4c^2\right)V^2 - V + V^{\uparrow} = 0$, which has solutions

$$V = \frac{1}{-V^{\uparrow}/2c^2}\left(+1 \pm \sqrt{1 - V^{\uparrow 2}/c^2}\right) \tag{5a}$$

Multiplying numerator and denominator by $\left(+1 \mp \sqrt{1 - V^{\uparrow 2}/c^2}\right)$ converts these to the form

$$V = V^{\uparrow}\Big/\frac{1}{2}\left(1 \mp \sqrt{1 - V^{\uparrow 2}/c^2}\right), \tag{5b}$$

which makes clear that for small $V^{\uparrow}$, V has one value much larger in magnitude than $V^{\uparrow}$ (which is negative there), and another value essentially equal to $V^{\uparrow}$

To see that v and $V^{\uparrow}$ are not only qualitatively *like* Einsteinian speed and covariant speed, but in fact quantitatively *equal* to them, one can do a bit more algebra Substitute (4b) into (3) and simplify to find

$$V^{\uparrow} = \mp v \Big/ \sqrt{1-V^2/c^2}\ , \tag{6a}$$

which is the definition of covariant speed familiar from SRT, made slightly more precise by inclusion of the minus sign for situations beyond the singularity

Similarly, substitute (19b) into (16) and simplify to find

$$v = \mp V^{\uparrow} \Big/ \sqrt{1+V^{\uparrow 2}/c^2}\ , \tag{6b}$$

which is again a relationship familiar from SRT, made slightly more precise by inclusion of the minus sign for situations beyond the singularity

The information contained in eqs (2)–(6a,b) is displayed graphically in Figure 2 Both plot axes denote multiples of nominal light speed c Galilean particle speed V is the independent variable To save space beyond the singularity, where $V^{\uparrow}$ goes negative, it is the absolute value of $V^{\uparrow}$ that is plotted

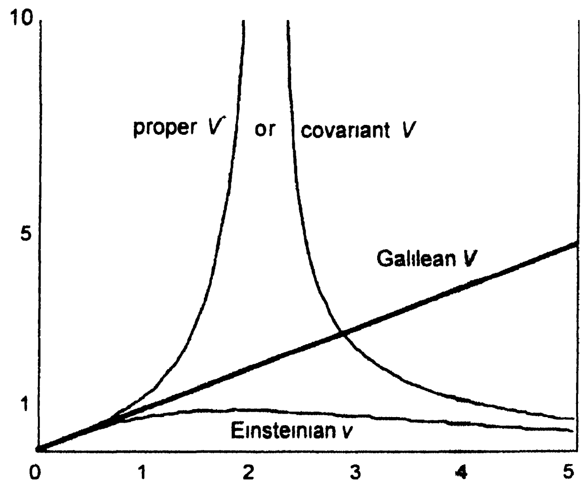

Figure 2. Numerical relationships among three speed concepts

Speed can be seen as a proxy for many other interesting things in SRT, like momentum, relativistic mass, *etc* Observe that with only two speed concepts, SRT only can offer only two speed relationships, whereas with three speed concepts, Two Step Light offers six speed relationships This constitutes three times the information content This is what makes Two Step Light a 'covering theory' for SRT Two Step Light offers additional opportunities for explaining all the interesting things in SRT

Two-Step Light theory resolves the directionality paradox inherent in the Lienard-Wiechert fields. Because of the various 2*c*'s in the mathematics, the radiation direction $\boldsymbol{n}_{\text{retarded}}$ changes to $\boldsymbol{n}_{\text{half retarded}}$, and the Coulomb attraction/repulsion direction $(\boldsymbol{n}_{\text{retarded}})_{\text{projected}}$ changes to $(\boldsymbol{n}_{\text{retarded}})_{\text{half projected}}$. These two directions are now physically the same; namely the source-to-receiver direction at the mid point of the scenario, *i.e.* $\boldsymbol{n}_{\text{mid point}}$. The potentials and fields become :

$$\boldsymbol{\Phi}(\boldsymbol{x},t) = e\left[1/R\right]_{\text{mid point}} \text{ and } \boldsymbol{A}(\boldsymbol{x},t) = e\left[\boldsymbol{V}/cR\right]_{\text{mid point}} \tag{7a}$$

and

$$\boldsymbol{E}(\boldsymbol{x},t) = e\left[\frac{\boldsymbol{n}}{R^2} + \frac{\boldsymbol{n}}{cR}\times\left(\boldsymbol{n}\times\frac{d\boldsymbol{V}}{cdt}\right)\right]_{\text{mid point}} \text{ and } \boldsymbol{B}(\boldsymbol{x},t) = n_{\text{mid point}}\times\boldsymbol{E}(\boldsymbol{x},t) \tag{7b}$$

so

$$\boldsymbol{P} = \boldsymbol{E}_{\text{radiative}} \times \boldsymbol{B}_{\text{radiative}} = \boldsymbol{E}_{\text{radiative}} \times (\boldsymbol{n}_{\text{mid point}} \times \boldsymbol{E}_{\text{radiative}})$$

$$= E^2_{\text{radiative}}\boldsymbol{n}_{\text{mid point}} \,. \tag{7c}$$

Observe that the Coulomb attraction or repulsion is now aligned with the direction of the radiation propagation.

4. Revisionist QM

Consider first the hydrogen atom. The electron orbits at radius r_e and the proton orbits at much, much smaller radius r_p. Figure 3 illustrates in an exaggerated manner how each experiences Coulomb attraction to the 'half-retarded' position of the other (as if the Coulomb force vector propagated at speed 2c).

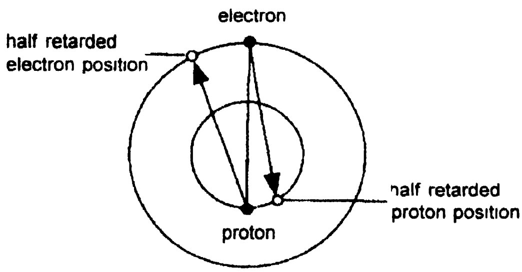

Figure 3. Coulomb force directions within the Hydrogen atom.

This situation implies that the forces within the Hydrogen atom are not central, and not even balanced. This situation has two major implications :

1. The unbalanced forces mean that the system as a whole experiences a net force. That means the system center of mass (C of M) can move.
2. The non-central individual forces, and the resulting torque, means the system energy can change.

These sorts of bizarre effects never occur in Newtonian mechanics But electromagnetism is not Newtonian mechanics In electromagnetic problems, the concepts of momentum and energy 'conservation' have to include the momentum and energy of fields, as well as those of matter Momentum and energy can both be exchanged between matter and fields 'Conservation' applies only to the system overall, not to matter alone (nor to fields alone either)

Looking in more detail, the unbalanced forces in the Hydrogen atom must cause the C of M of the whole atom to traverse its own circular orbit, on top of the orbits of the electron and proton individually This is an additional source of accelerations, and hence of radiation It evidently makes even worse the original problem of putative energy loss by radiation that prompted the development of QM But on the other hand, the torque on the system implies a rate of energy gain to the system This is a candidate mechanism to compensate the rate of energy loss due to radiation That is why the concept of 'balance' emerges there can be a balance between radiation loss of energy and torquing gain of energy

The details are worked out quantitatively as follows First, ask what the circulation can do to the radiation A relevant kinematic truth about systems traversing circular paths was uncovered by L H Thomas back in 1927, in connection with explaining the then-anomalous magnetic moment of the electron just half its expected value [8] He showed that a coordinate frame attached to a particle driven around a circle naturally rotates at half the imposed circular revolution rate Figure 4 illustrates

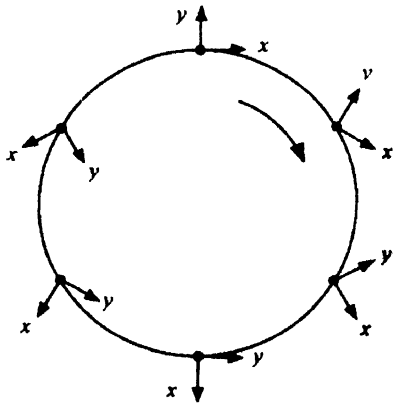

Figure 4. Thomas rotation When the particle traverses the full circle, its internal frame of reference rotates 180°

Applied to the old scenario of the electron orbiting stationary proton, the gradually rotating x, y coordinate frame of the electron meant that the electron would see the proton moving only half as fast as an external observer would see it That fact explained the electron's anomalous magnetic moment, and so was received with great interest in its day But the fact of Thomas rotation has since slipped to the status of mere curiosity, because Dirac theory has replaced it as the favored explanation for the magnetic moment problem Now, however, there is a new problem in which to consider Thomas rotation the case of the C of M of a whole Hydrogen atom being driven in a circle by unbalanced forces In this scenario, the gradually rotating local x, y coordinate frame of the C of M means that the atom system doing its internal orbiting at frequency Ω_e relative to the C of M will be judged by an external observer to be orbiting twice as fast, at frequency $\Omega' = 2\Omega_e$ relative to inertial space This perhaps surprising result can be established in at least three ways

1 By analogy to the original problem of the electron magnetic moment,

2 By construction of Ω' in the lab frame from Ω_e in the C of M frame as the power series $\Omega' = \Omega_e \times \left(1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \quad \right) \to \Omega_e \times 2$,

3 By observation that in inertial space Ω' must satisfy the algebraic relation $\Omega' = \Omega_e + \Omega'/2$, which implies $\Omega' = 2\Omega_e$

The relation $\Omega' = 2\Omega_e$ means the far field radiation power, if it really ever manifested itself in the far field, would be even stronger than classically predicted The classical Larmor formula for radiation power from a charge e (e in electrostatic units) is $P_e = 2e^2a^2/3c^3$ where a is total acceleration For the classical electron-proton system, most of the radiation comes from the electron orbiting with $a_e = r_e\Omega_e^2$, Ω_e but with $\Omega' = 2\Omega_e$, the effective total acceleration is $a' = a_e \times 2^2$ With electron-proton total separation nominally $r_e + r_p$, the Coulomb force is approximately $F_e = e^2/(r_e + r_p)^2$, $a_e = F_e/m_e$, and the total radiation power is approximately

$$P_R = 2^4\left(2e^2/3c^3\right)a_e^2 = 2^5\left(e^6/m_e^2\right)/3c^3\left(r_e + r_p\right)^4 \tag{8a}$$

However, that outflow of energy due to radiation is never manifested in the far field beause it is compensated by an inflow of energy due to the torque on the system This is what overcomes the main problem about Hydrogen that was a main driver in the development of QM, namely, that the Hydrogen atom ought to run down due to radiative energy loss

Generally, the inflow power $P_T = T\Omega_e$, where T is the total torque $T = \left|\boldsymbol{r}_e \times \boldsymbol{F}_e + \boldsymbol{r}_p \times \boldsymbol{F}_p\right|$, and $\boldsymbol{r}_e \times \boldsymbol{F}_e \equiv \boldsymbol{r}_p \times \boldsymbol{F}_p$, so $T = 2\left|\boldsymbol{r}_e \times \boldsymbol{F}_e\right|$ With two-step light, the angle between $\boldsymbol{r}_e$ and $\boldsymbol{F}_e$ is $r_p\Omega_e/2c = \left(m_e/m_p\right)\left(r_p\Omega_e/2c\right)$ So the torque $T = \left(m_e/m_p\right)\left(r_e\Omega_e/c\right)\left[e^2/\left(r_e + r_p\right)\right]$ and the power

$$P_T = \left(m_e/m_p\right)\left(r_e\Omega_e^2/c\right)\left[e^2/\left(r_e + r_p\right)\right] = \left(e^4/m_p\right)/c\left(r_e + r_p\right)^3 \tag{8b}$$

Now posit a balance between the energy gain rate due to the torque and the energy loss rate due to the radiation. The balance requires $P_T = P_R$, or

$$\left(e^4/m_p\right)/c\left(r_e+r_p\right)^3 = \left(2^5 e^6/m_e^2\right)/3c^3\left(r_e+r_p\right)^4 . \tag{8c}$$

This equation can be solved for $r_e + r_p$:

$$r_e + r_p = 32 m_p e^2/3 m_e^2 c = 5.5 \times 10^{-9} \text{ cm}. \tag{9a}$$

Compare this value to the accepted value $r_e + r_p = 5.28 \times 10^{-9}$ cm. The match is fairly close, running just about 4% high. That means the concept of torque *versus* radiation does a fairly decent job of modeling the ground state of Hydrogen

The result concerning the Hydrogen atom invites a comment on Planck's constant h, which is generally presumed to be a fundamental constant of Nature. In conventional QM, $r_e + r_p$ is expressed in terms of h :

$$r_e + r_p = h^2/4\pi^2 \mu e^2 . \tag{9b}$$

Here μ is the so-called 'reduced mass', defined by $\mu^{-1} = m_e^{-1} + m_p^{-1}$. Using $\mu \approx m_e$ in (13b) and equating (13b) to (13a) gives

$$h \approx \frac{\pi e^2}{c}\sqrt{128 m_p/3 m_e} . \tag{10}$$

This expression comes to a value of 6.77×10^{-34} Joule-sec, about 2% high compared to the accepted value of 6.626176×10^{-34} Joule-sec. Is this result meaningful ? To test it, a more detailed analysis accounts more accurately for 'sin' and 'cos' functions of the smalle angle $r_p\Omega_e/2c$, here represented by the small angle itself, and by unity. That exercise makes the estimate of h more accurate too, and suggests that the model is indeed meaningful, and that Planck's constant need not be regarded as an independent constant of Nature.

The analysis so far is for the ground state of Hydrogen. To contribute to a covering theory for QM, that analysis has to be extended, first to cover trans-Hydrogenic atoms, and then to cover the so-called 'excited states' of Hydrogen, and the trans-Hydrogenic atoms, and even molecules.

The first concept for creating extensions is to replace the proton in Hydrogen with other nuclei. This replacement immediately gives the reason for the *M/Z* scaling used throughout this paper. With replacement, the subscript p for proton changes to Z. Eqs. (12a) and (12b) are both scaled by Z^2, and (12b) is additionally scaled by $1/M$. As a result, (13a) changes to $r_e + r_Z = M\left(r_e + r_p\right)$. The electron energy in the Hydrogen case is $E_H = e^2/\left(r_e + r_p\right)$; for the element Z case, the e^2 changes to Ze^2, so overall, the single-electron energy changes to

$$E_Z = Ze^2/M(r_e + r_z) = (Z/M)\,E_H \,. \tag{11}$$

If it weren't for neutrons, the scale factor *Z/M* would be unity. But because of neutrons *Z/M* varies from 1 for Hydrogen, immediately to 0.5 for Helium, and eventually to 0.4 for the heaviest elements we presently know about. So in order to put the *IP* data for different elements onto a common basis, we must remove the *Z/M* factor from raw data by scaling with its inverse *M/Z*.

The second concept for creating extensions is to replace the single electron and single proton in Hydrogen with multiple electrons and multiple protons (with neutrons too), charges of each sign bound in coherent subsystems called 'charge clusters'. In the journal Galilean Electrodynamics, we have occasionally had reports and commentary about the apparently incomprehensible phenomenon of electrons clustering together [12–14]. The phenomenon is widely known; related literature cited in the third of those references is quite extensive and some of it appears in the most widely circulated physics journals.

The idea of charge clusters suggests a new interpretation of 'excited' states for Hydrogen The conventional idea involves an electron teetering in an upper 'shell', ready to fall back to a lower 'shell'. But the present simple two-body analysis of Hydrogen does not allow anything so complicated. The simple torque *vs.* radiation balance has only one low-speed solution, corresponding to the ground state. That means the term 'excited state' cannot describe a condition of a single Hydrogen atom. So it has to describe a system of multiple Hydrogen atoms

Support for an excitation model based on multiple atoms comes from the known fact that light emission is always a little bit laser-like, in that photons are emitted, not as singletons, but rather in bursts [15] This behavior suggests that atoms become excited not as singletons, but as groups. So suppose that 'excitation' of Hydrogen up to state n actually involves $n = n_H$ Hydrogen atoms all working together in a coherent way. In particular suppose that the n_H electrons make a negative cluster, and the n_H protons make a positive cluster, and the two clusters together make a scaled-up Hydrogen super-atom.

The replacement of single charges with charge clusters must affect both the radiation energy loss rate and the torquing energy gain rate, and the balance between them. Every factor of e and every factor of m_e or m_p scales by n_H. Starting from (8a) for the radiation, one finds that the energy loss rate scales by n_H^4. Starting from (8b) for the torquing, one finds that the energy gain rate scales by n_H^3. The solution radius for system balance therefore scales as $r_e + r_p \rightarrow r_{n_H} = n_H\left(r_e + r_p\right)$. [Note : if this multi-atom model captures the real behavior behind atomic excitation, and if one attempts to model that behavior in terms of a single atom with discrete radial states identified with a principal quantum number n, then the radial scaling has to be $r_1 \rightarrow r_n = n^2 r_1$, as is seen in standard QM.]

The overall system orbital energy then scales as $E_1 \rightarrow E_{n_H} = n_H^2 E_1 / n_H = n_H E_1$ This energy result is exactly the same as the orbital energy of n_H *separate* atoms *not* clustered together in a super atom The implication is that when the system disintegrates, the energy that exits as photons does *not*, as is generally believed, correspond to an orbit around the nucleus It is instead the positive energy required to form the charge clusters If any kind of 'orbit' is involved, it is an orbit, not around the nucleus, but rather internal to the charge cluster This is a completely novel view of excitation

Spectroscopic data indicates that the energy required to bring the n_H^{th} Hydrogen atom from complete separation to complete integration into an existing super atom of $n_H - 1$ atoms thus forming a super atom of n_H atoms, is $|E_1|\left[(n_H - 1)^{-2} - n_H^{-2}\right]$ The inverse squares can be understood as follows The radial scaling $r_{n_H} = n_H(r_e + r_p)$ suggests that all linear dimensions scale linearly with n_H If so, the volume of the clusters scales as n_H^3 The number density of charges in clusters therefore scales as $n_H / n_H^3 = n_H^{2}$ The positive energy locked in the pair of clusters therefore depends on the number density in the clusters This is something like having energy proportional to pressure, as is seen in classical thermodynamics

5 Discussion

An important factor presently limiting scientific development is Einstein's Second Postulate concerning light speed We do not have to retain that Postulate We can consider other postulates instead, and adopt another one if it works better For example, we can adopt Two Step Light In that case, what comes out is a covering theory for Einstein's SRT Since it contains SRT, researchers who are happy with SRT need not sacrifice anything But researchers who need something more can perhaps find something they need in Two Step Light Contrasts such as 'Lorentzian' *vs* 'Galilean' [16] disappear

For example, expanding SRT allows one to adopt an approach for understanding atoms that is completely different from traditional QM We need not postulate the value of Planck's constant, or the nature of its involvement in the mathematics of 'probability' waves, *etc* Planck's constant can be an output *from*, rather than an input *to*, the variant theory for atoms The resulting theory has already produced interesting applications in chemistry [17–20]

The extended SRT and revised QM together serve to reassert the importance of classical electrodynamics as a basis for ongoing scientific development The focus on electrodynamics opens up the possibility for a different attack on the problem of unifying GRT and QM Previously, Einstein's GRT was based upon Einstein's SRT, which was in turn based on Maxwell's EMT, which failed on the problems that led to the development of QM Developed along those paths, GRT and QM are unlikely ever to be unified But with new development paths that are based on classical electrodynamics, hope for unification is rekindled

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All Figures in this paper appeared originally in shorter works in Galilean Electrodynamics or in Proceedings of the Natural Philosophy Alliance, and are reproduced here with permission

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